

The Lava Beneath Our Feet

Rock Cores from Tom Cat Hill, East
Highway 20/26/93 Improvement Project



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In partnership with the National Park Service, Bureau of Land Management, Association of
Women Geoscientists, and The Geological Society of America

Summer 2008



Introduction

In 2003, twenty-nine bore holes were drilled into the prospective route for Southeastern Idaho's Highway 20/26/93. Cores were collected from these bore holes in order to determine ground stability prior to emplacement of a new section of highway. Ruen drilling extracted the basaltic cores along a two mile stretch reaching depths below the surface of up to six meters. Although the purpose of these cores was to improve highway routes, geologists at Craters of the Moon National Monument have also taken advantage of this opportunity to learn more about the lava beneath their feet and incorporate this with their knowledge of the surface.

Location

The cores were drilled approximately six miles southwest of the entrance to Craters of the Moon National Monument and Preserve along the current trace of Highway 20/26/93 (Figure 1). Below the map is an inset of the improved section of the highway with the borehole locations for the core samples shown (Figure 1a). The specific location for each individual bore hole is listed later in the report under the bore hole number.

Background of the Lava Flows

The 29 cores were mainly collected from a single basalt flow and contain minor amounts of soil and old road embankment. The lava flow that comprises the majority of the core is part of the Grassy Cone flow. This surface- and tube-fed pahoehoe flow erupted from Grassy Cone approximately 7300 years ago. The lava that originated from Grassy Cone, north of what is now Highway 20/26/93 flowed north abutting the high peaks of the Pioneer Mountains as well as flowing south as far as 11.5 miles. A second, older flow may also be present within two of the deeper cores. Evidence for the presence of a second flow is the transitional contact between massive basalt with few vesicles to basalt with a pahoehoe texture. Evidence suggests that the older flow may be the pahoehoe textured Sunset cone flow, which erupted from Sunset Cone directly to the northeast of Grassy Cone approximately 12,000 years ago. Based on age and location the other possible identity for the second flow could be the Carey A'A' flow. However, the flow at the base of the bore holes had a ropery, pahoehoe texture and the Carey flow has a blocky, A'A' texture, therefore the most likely candidate for the second unit is the Sunset Cone flow. The remaining lava flows in the vicinity of the bore holes are all much too young to lie below the Grassy Cone Flow and are therefore ruled out as possible candidates for the second unit. Figure two shows a geologic map with all the lava flows in the general area of the section of highway labeled. Details on the age, lava type, and source for each flow are listed below in Table 1 (Kuntz and others, 1986).

Table 1. Characteristics of lava flows in close proximity to bore holes. Absolute ages ($7,360 \pm 60$) were determined using radiocarbon dating, while relative ages (~) are based upon paleomagnetic and stratigraphic evidence. (Kuntz and others, 1986)

Flow	Flow Nomenclature	Predominant Lava Type	Age (years ago)	Eruptive Period	Source Vents	Estimated Area (km ²)	Average Thickness (m)	Estimated Volume (km ³)
Blue Dragon	Qfa2p	pahoehoe	$2,076 \pm 45$	A	Eruptive Fissures S. of Big Craters	280	12	3.4
Highway	Qfa8b	a' a	~ 2,250	A	North Craters Cinder Cone (?) or vent between Grassy and Sunset cones (?)	1.5	20	0.03
North Crater	Qfa5p	pahoehoe	~ 2,300	A	North Crater Cinder Cone	1.5	5	0.01
Big Craters	Qfa5p	pahoehoe	$2,400 \pm 300$	A	Eruptive Fissures N. of Big Craters	9	5	0.05
Silent Cone	Qfd1p	pahoehoe	~ 6,450	D	Silent Cone Cinder Cone	9	15	0.1
Grassy Cone	Qfe1p	pahoehoe	$7,360 \pm 60$	E	Grassy Cone Cinder Cone	120	10	1.2
Carey	Qfg2a	a' a	~ 12,000	G	Sunset Cone Cinder Cone	230	12	2.8
Sunset	Qfg1p	pahoehoe	$12,010 \pm 120$	G	Sunset Cone Cinder Cone	100	10	1.0

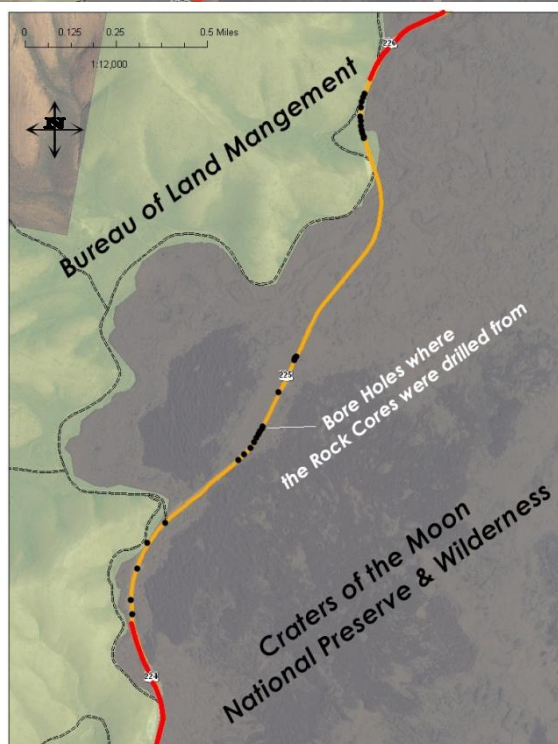
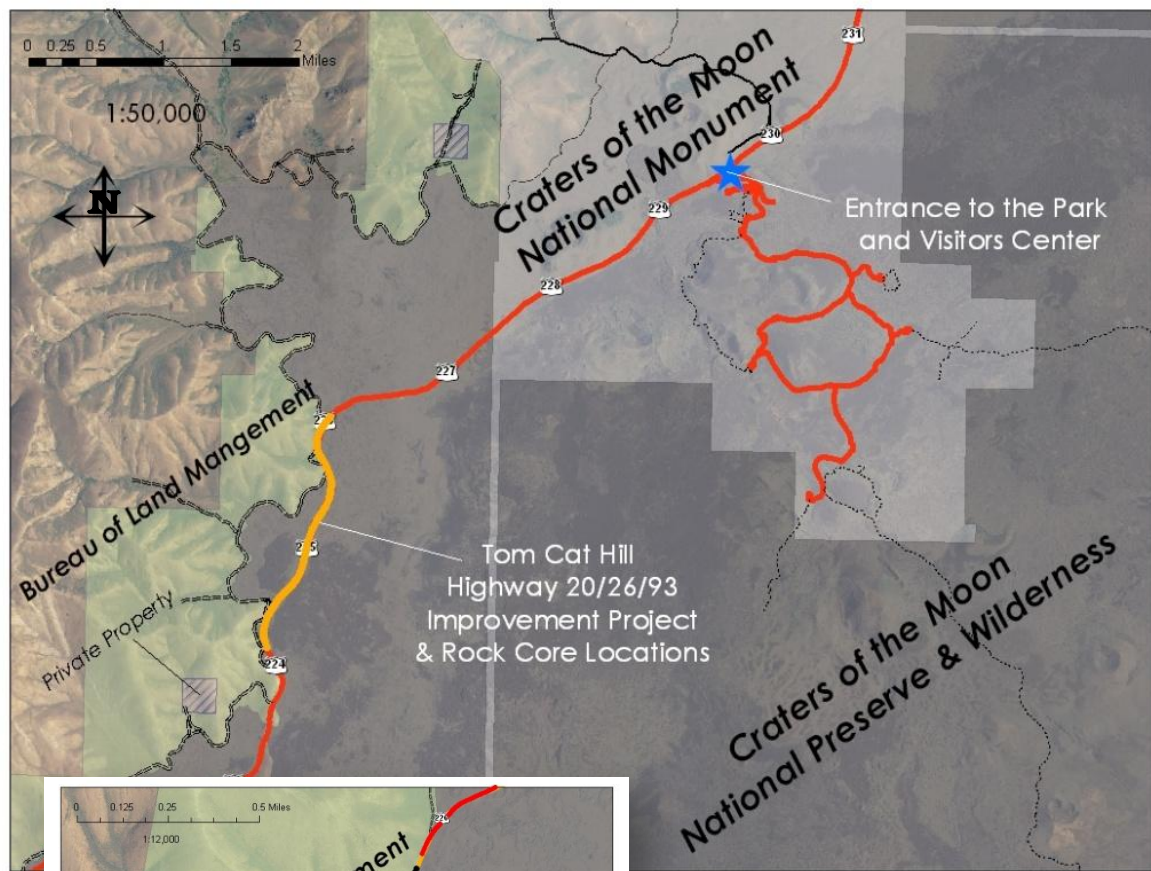


Figure 1 (above): Boundary map of Craters of the Moon National Monument and Preserve. Background image is composed of stitched aerial photos from the National Agricultural Imagery Program. Rock Cores were taken from boreholes drilled along the orange section of Idaho Highway 20/26/93 displayed in red. The entrance to the park and Visitor's Center is marked by the blue star.

Figure 1a (left): Inset of Figure 1 which displays specific locations for individual boreholes.

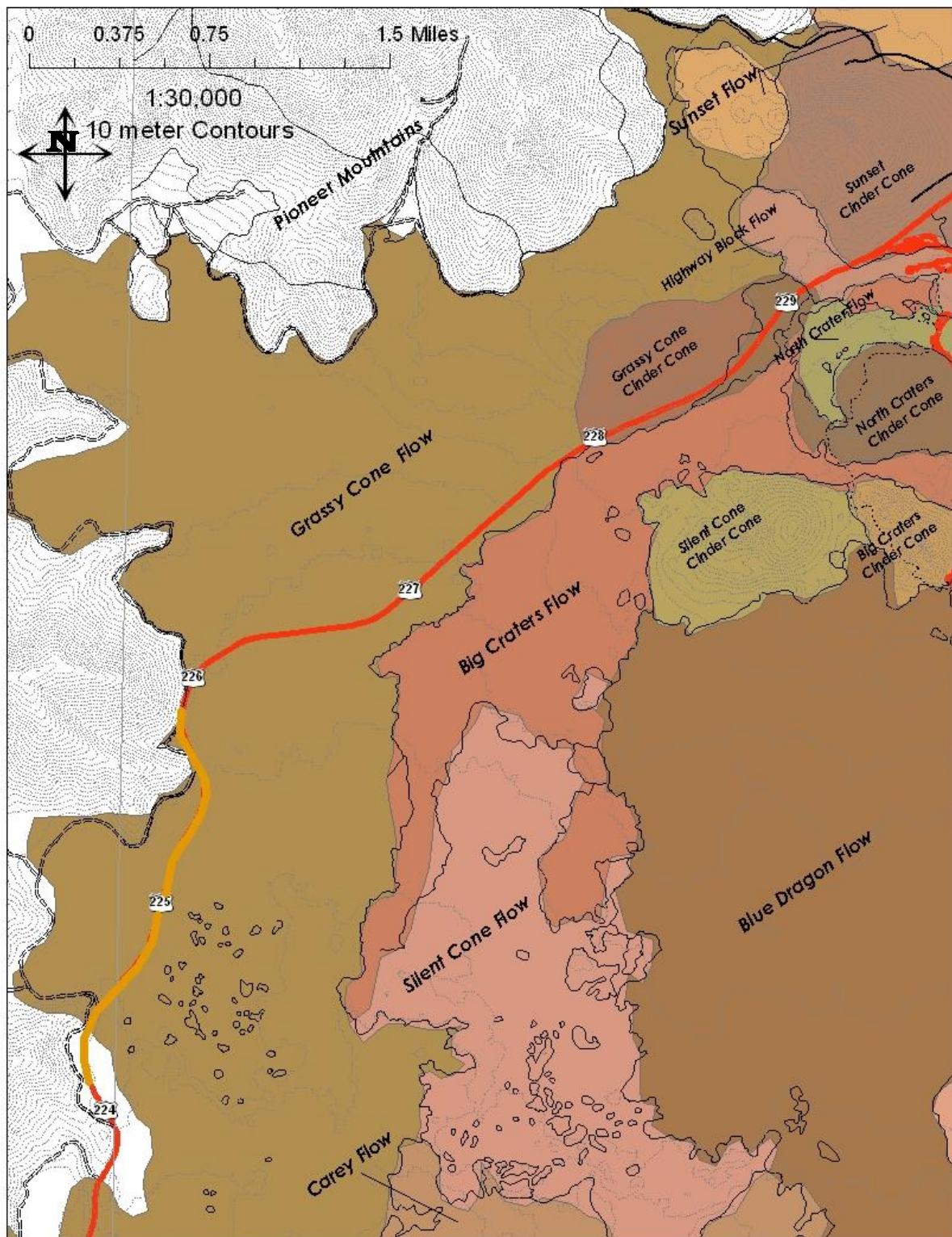



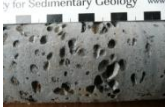





















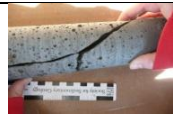








Figure 2: Geologic map of the lava flows in the northwestern segment of Craters of the Moon National Monument and Preserve. Rock cores mainly contain basalt from the Grassy Cone Flow, but also possibly contain small amounts of the Sunset Flow. For overview of flows see Table 1. (modified from Kuntz et al, 2007)

Understanding the nature of the flows and the formation of the rock is not always straight forward. However, by associating the observed features of the rocks to particular igneous processes as well as comparing the spatial distribution of the lava flows makes it possible to better understand the volcanic episodes that occurred (Winters, 2001). Conversely, there is a plethora of geological terms that can be used to define and describe these observed lava features; covering a wide range of aspects. Mostly encompassing the chemical and physical characteristics of the rocks, the terminology associates the feature to a definitive igneous process. In order to readily describe the rock cores, specific vocabulary used is defined by the legend in Table 2.

Symbol	Term	Definition / Description	Picture
	Massive Basalt	A basaltic rock with homogeneous texture, lacks flow layering and foliation, but may contain few vesicles	
	Vesicular Basalt	A textural characteristic of a basaltic rock that contains glassy cavities created by the release of gas or steam	
	Weathered Basalt	A basaltic rock that underwent the destructive processes of the atmosphere and its agents causing the breakdown of the rock	
	Soil	Unconsolidated material above the bedrock	
	Roadway Embankment of Basalt & Soil & Clay	Pile of rock or soil as well as pieces of the basaltic bedrock that was built up to support the old highway route	
	Void	Section of the core that is incomplete or missing	
	Slightly Vesicular	A rock containing a small number of vesicles (gas bubbles)	
	Highly Vesicular	A rock containing a significant number of vesicles, which are most often concentrated near the surface of the flow	
	Transition: Slightly to Highly Vesicular	Within a single lava flow the abundance of vesicles tends to decrease with increasing distance from flow margins	
	Oxidized Vesicles	Vesicles which contain minerals that chemically combined with oxygen leaving a reddish stain on the rocks	
	Ropey	A low viscosity basalt flow that has a texture resembling ropes (also known as pahoehoe)	
	Root	The part of plants that extracts nutrients from soil	

	Joints: 90°, 80°, 70°, 45°, & 20°	Parting in the rock where no displacement has occurred, but a loss of cohesion chemically, which can occur at various angles	
	Joint: filled with soil	Within some of the rock partings soil and sometimes roots were found	
	Core Sample	<div data-bbox="738 535 1388 745"> <p>Table 2. Legend explaining symbols and defining terms for core diagrams below. Sizes of vesicles in the diagram are relative to actual size of vesicles within the rock cores. (Winters, 2001), (Bates, 1984)</p> </div>	
	Borehole of selected core		
	Highway 20/26/93		
	Depth from surface		

Core Sample Descriptions

Each core that was drilled from the Tom Cat Hill, East project was originally described by Shawn Enright. His boring logs show the subsurface conditions at the locations and times the borings were drilled (Enright, 2004). From his descriptions, as well as our own we created a diagram of each core sample to show the lava features in detail. The legend explaining the symbols and defining the terminology is located in Table 2. The top of each diagram represents the surface level at that location. For each core the depth is calculated by setting the surface level to 0 and then measuring from this point down in meters. All measurements are labeled in meters including borehole collar elevations (1 meter = 3.28 feet). The cores are spatially ordered with BH-29 (followed by BH-1, BH-2,...) starting in the southwest and ending with BH-28 in the northeast (Figure 3).

BH-29

With a starting elevation of 1763.22 meters, core sample 29 was drilled to a total depth of 3.05 meters. From the surface to 1.22 meters of depth, this section of the core is highly vesicular basalt with a joint at 0.46 meters. At 1.22 meters down to 3.05 meters the core develops into massive basalt with few large vesicles. Sample P901 was pulled from the core at a depth of 1.98 to 2.13 meters.



BH-1

With a surface elevation of 1761.13 meters, core sample 1 was drilled to a total depth of 5.03 meters. The first 2.44 meters are highly vesicular basalt with weathered joints that are roughly 80 degrees. The rest of the core to its final depth of 5.03 meters is comprised of massive basalt with few vesicles.



BH-2

With a surface elevation of 1764.78 meters, core sample 2 was drilled to a total depth of 4.72 meters. From the surface to 1.83 meters the basalt was highly vesicular, with a transition to massive basalt with fewer vesicles. The core remained massive to its total depth of 4.72 meters. A sample P902 was removed from 2.31 to 2.46 meters. Also, there is a void of roughly .150 millimeters at the depth of 3.51 meters.

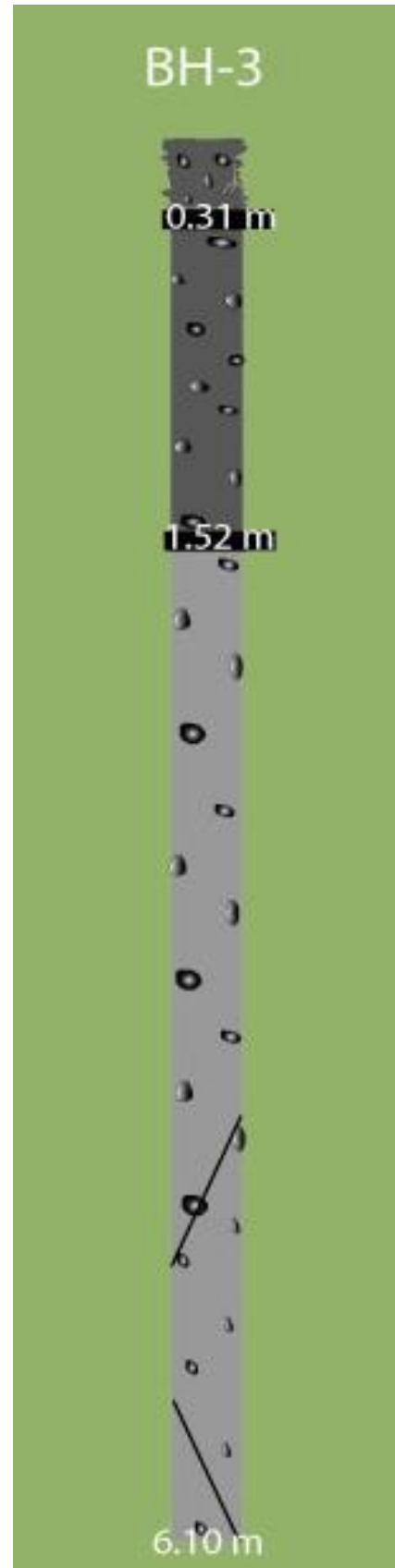


BH-3

With a surface elevation of 1765.08 meters, core sample 3 was drilled to a total depth of 6.10 meters. Highly weathered basalt comprises the first .31 meters

from the surface then transitions into more massive basalt with larger vesicles down to 1.52 meters of depth. From 1.52 meters down to the final depth of 6.10 meters, it becomes slightly more vesicular. At 2.9 meters, begins a zone of broken up core and at 4.27 meters as well as

5.79 meters there are joints of 70 degrees. Sample P903 was removed from 3.81 to 3.96 meters.



BH-4

With a surface elevation of 1765.56 meters, core sample 4 was drilled to a total depth of 4.57 meters. The core transitions from highly vesicular to massive as it

increases with depth. Beginning at the surface to 0.91 meters the basalt is highly vesicular. From 0.91 meters to 1.52 meters the basalt becomes more massive with larger vesicles. At 1.52 meters the basalt becomes notably more massive due to the decrease in vesicle abundance, although less abundant the size of the vesicles begins to increase in size with depth. This pattern continues until 3.35 meters

in depth where it is massive down to the core's total depth of 4.57 meters. Sample P904 was removed from 3.66 meters to 3.81 meters.



BH-5

With a surface elevation of 1766.17 meters, core sample 5 was drilled to a total depth of 5.03 meters. Weathered basalt and soil make up the first 0.2

meters of this core. From 0.2 to 0.76 meters the basalt is highly vesicular. From 0.76 to 1.98 meters it becomes slightly weathered. Sample P905 was taken from this zone of slightly weathered basalt from 1.12

meters down to 1.27

meters. At

1.98 meters

the basalt is

once again

unweathered

and slightly

vesicular. The

basalt is

massive

below 3.51



meters with joints of 70 degrees from 4.27 meters to the base of the core at 5.03 meters.



BH-6

With a surface elevation of 1766.45 meters, core sample 6 was drilled to a total depth of 4.75 meters. From the surface to 0.15 meters, the core consists of loose rock and soil, below which it

becomes highly vesicular basalt. The basalt remains highly vesiculated down to 1.22 meters at which point the abundance of vesicles decrease. At 2.29 meters the core transitions to

massive basalt which continues to the bottom of the borehole at a depth of 4.75 meters.

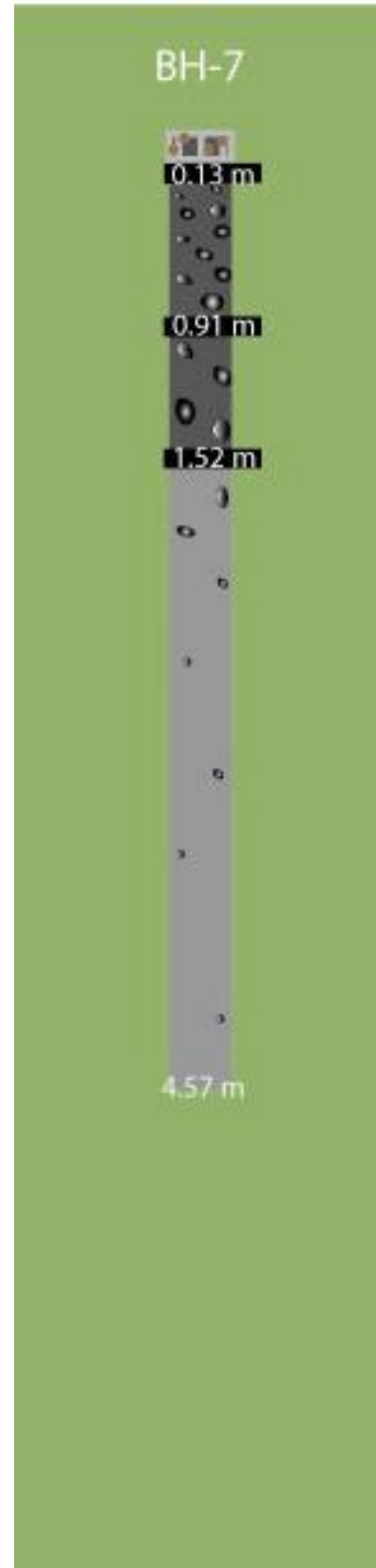


BH-7

With a surface elevation of 1766.44 meters, core 7 was drilled to a total depth of 4.57 meters. The first 0.13 meters were comprised of loose rock and soil, from there the basalt was highly vesicular

with joints of 70 degrees down to 0.91 meters. Subsequently, the basalt became less vesicular down to 1.52 meters where the basalt transitioned to a more massive unit with fewer vesicles, the basalt remained this way to the

bottom of the hole at 4.57 meters. Noted was a small void from 4.27 to 4.41 meters.



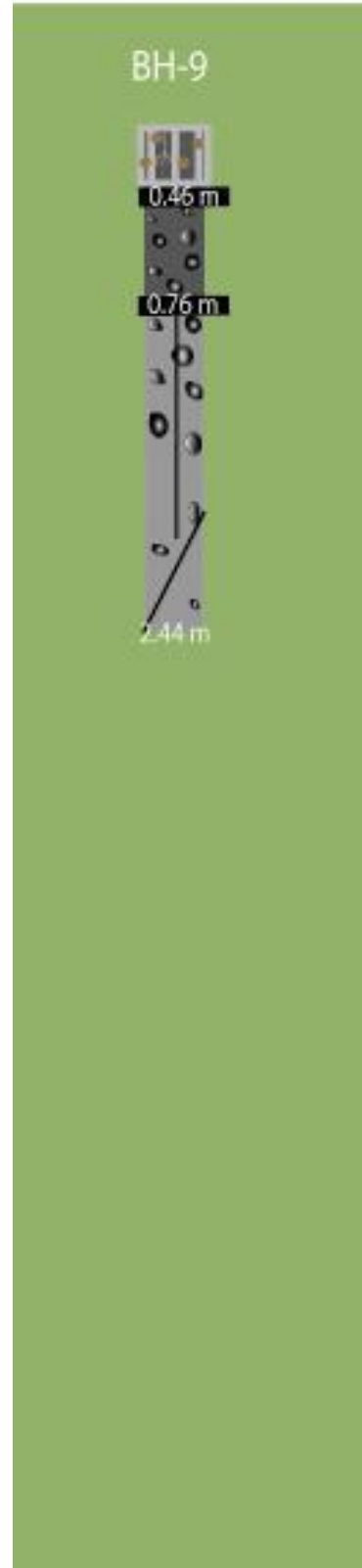
BH-8

With a surface elevation of 1766.36 meters, core 8 was drilled to a total depth of 3.15 meters. Loose rock and soil comprised the first 0.47 meters. Below the loose rock and soil highly vesicular basalt was present down to 1.52 meters. Between 0.89 meters to 1.04 meters down sample P906 was pulled from the core. At 1.52 meters the basalt becomes massive and stays this way to the bottom of the hole. Joints at 45 degrees occur both at 1.67 meters and again at 2.64 meters.



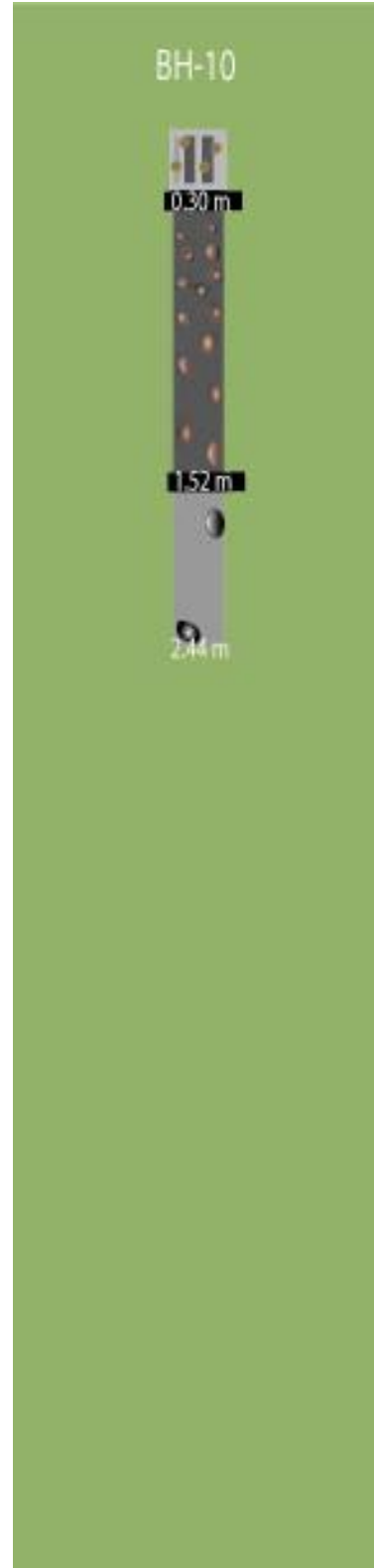
BH-9

With a surface elevation of 1766.45 meters, core 9 was drilled to a total depth of 2.44 meters. The first 0.46 meters was dominated by loose rock and soil, followed by highly vesiculated basalt down to 0.76 meters. From this point the core transitions to a more massive texture and is significantly jointed. The joints have angles of 90 degrees between 0.76 to 1.83 meters and 70 degrees from 2.06 to the bottom of the hole at 2.44 meters.



BH-10

With a surface elevation of 1766.41 meters, core 10 was drilled to a total depth of 2.44 meters. From the surface to the depth of 0.3 meters, the core consists of loose rock and soil, followed by highly vesicular basalt down to 1.52 meters. In this section of the core the vesicles were red due to oxidation of the iron minerals within the rock. At 1.52 meters the basalt transitions from vesicular to more massive. The basalt remains massive to the base of the hole at 2.44 meters.



BH-11

With a surface elevation of 1766.09 meters, core 11 was drilled to a total depth of 4.57 meters. Loose rock and soil is present from the surface to 0.20 meters in depth.

Highly vesicular basalt is found from 0.20 to 1.52 meters, where the vesicles begin to decrease in size with depth. In a transitional zone between 1.52 to 3.05 meters, the core becomes less vesicular and more massive. At 3.05 meters the basalt is completely massive with 70 degree joints at 3.96 meters and 4.27 meters. The basalt remains massive to the base of the hole.



BH-12

With a surface elevation of 1766.43 meters, core 12 was drilled to a total depth of 4.57 meters. Highly vesicular basalt is found within the first section of this core from the surface down to 1.83 meters. There is a zone of jointing between 1.52 to 1.83 meters. Just above 1.52 meters there is one 90 degree joint, while within the zone of jointing, the joints occur at 45 and 70 degree angles. From 1.83 meters to the base of the hole the core is massive, and contains a

mineralized void at 2.44 to 2.59 meters.



BH-13

With a surface elevation of 1766.33 meters, core 13 was drilled to a total depth of 3.05 meters. The top 0.15 meters of the core consists of loose rock and soil. From 0.15 to 0.3

meters vesicular basalt is present without any evidence of soil. At 0.3 meters there is a soil filled joint where slightly vesiculated basalt begins and continues to the base of the hole.

There are four joints, all at 70 degrees,

occurring at 1.67, 2.13, 2.29, and 2.74 meters.

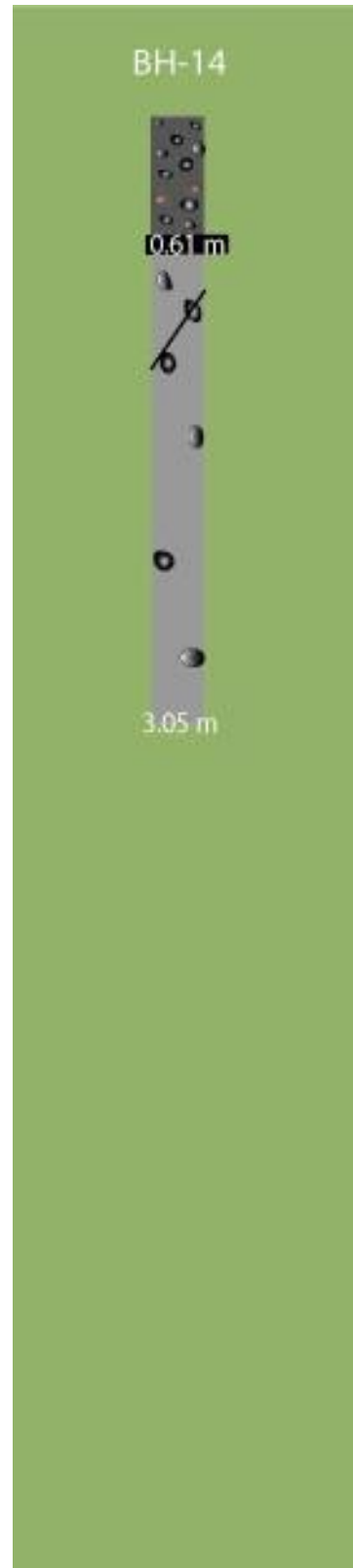


BH-14

With a surface



elevation of 1766.85 meters, core 14 was drilled to a total depth of 3.05 meters. This top of this core down to 0.61 meters consists of highly vesicular basalt. Massive basalt follows and continues to the bottom of the hole. One joint is present at 1.07 meters.



BH-15

With a surface elevation of 1767.55 meters, core 15 was drilled to a total depth of 2.44 meters. Similar to BH-14, the first 0.61 meters is highly vesicular, but this core is also slightly weathered. At 0.61 meters, the core transitions to massive basalt with numerous joints. The joints are at 45 degree angles at 1.68, 1.83, and 1.93 meters. The basalt continues to be massive to the bottom of the hole.



BH-16

With a surface elevation of 1767.72 meters, core 16 was drilled to a total depth of 2.13 meters. The core contains some loose rock and soil down to 0.2 meters. Then the core changes abruptly to highly vesicular basalt. At 1.07 meters, the core transitions to massive basalt, which continues to the bottom of the hole. There is one vertical joint at 1.9 meters.



BH-17

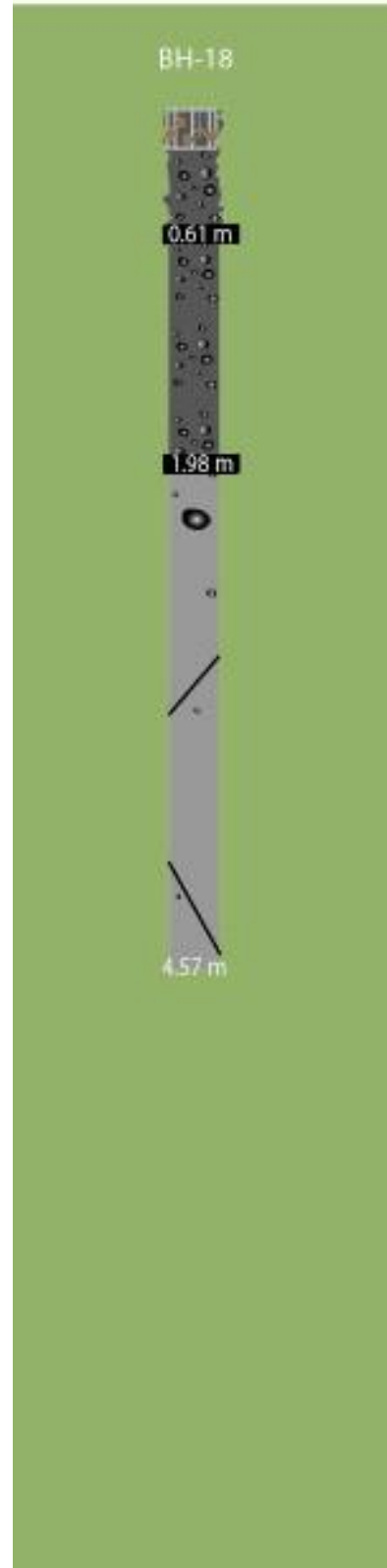
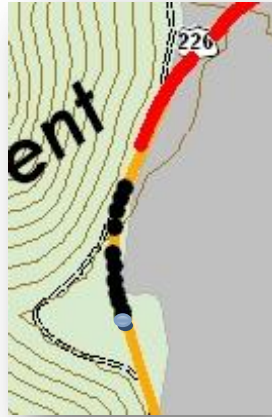
With a surface elevation of 1768.47 meters, core 17 was drilled to a total depth of 2.44 meters. The core

contains weathered basalt with clay down to 0.31 meters, where it changes to highly vesicular basalt that continues to 1.21 meters. A small transition to slightly vesicular basalt is marked by a clay-filled joint at 1.21 meters. The zone of vesiculation ends at 1.52 meters where the basalt becomes massive and remains so to the bottom of the hole. There is one joint at 1.98 meters.



BH-18

With a surface elevation of 1780.23 meters, core 18 was drilled to a total depth of 4.57 meters. Highly weathered, vesicular basalt is found in the first 0.61 meters of core. The next section of basalt is massive with vesicular zones 150 to 200 millimeters thick. The section ends at 1.99 meters where the basalt remains massive to the base of the hole. There are joints at 3.05 and 4.27 meters.



BH-19

With a surface elevation of 1780.49 meters, core 19 was drilled to a total depth of 3.05 meters. The first part of the core which incorporates the surface down to 1.52 meters

contains highly vesicular basalt with a small broken zone between 0.61 to 0.76 meters. Within the broken zone the vesicles are red due to oxidization. The rest of the core from 1.52 meters down to the bottom of the hole is massive with two small voids about 75 millimeters wide between 2.74 and 3.05 meters.



BH-20

With a surface elevation of 1780.59 meters, core 20 was drilled to a total depth of 4.57 meters. Loose rock and soil is present at the top of the core and ends at 0.15 meters. The next section is highly vesiculated basalt down to 0.61 meters with small joints at 70 degrees. There is a tiny section of ropy vesicular basalt between 0.61 and 0.76 meters. It is vesicular down to 1.23 meters, where there is another small section of ropy vesicular basalt down to 1.38 meters. Down to 1.98 meters the core is highly vesicular. From 1.98 meters to the bottom of the hole the basalt is massive.



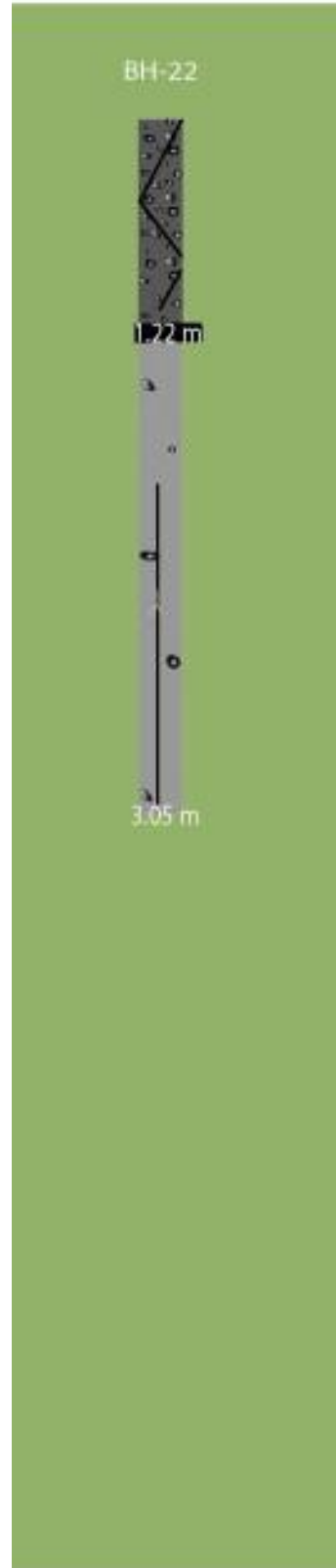
BH-21

With a surface elevation of 1780.59 meters, core 21 was drilled to a total depth of 3.05 meters. Loose rock and soil is only present for the first 0.1 meter of the core. At this point there is a transition from loose rock and soil to highly vesicular basalt which continues to 0.91 meters with two 70 degree joints at 0.30 meters and 0.91 meters. Small interlayers of vesiculated and non-vesiculated basalt extend down to 1.39 meters. From 1.39 meters to the base of the core the basalt is massive. One 45 degree joint is present at 1.66 meters.



BH-22

With a surface elevation of 1780.93 meters, core 22 was drilled to a total depth of 3.05 meters. From the surface to 1.22 meters this core is highly vesicular with three joints present at various angles (0.15, 0.61, and 1.22 meters). The deepest part of the core is massive with vertical joints from 2.13 meters to the base of the hole. Roots were found within the vertical joints.



BH-23

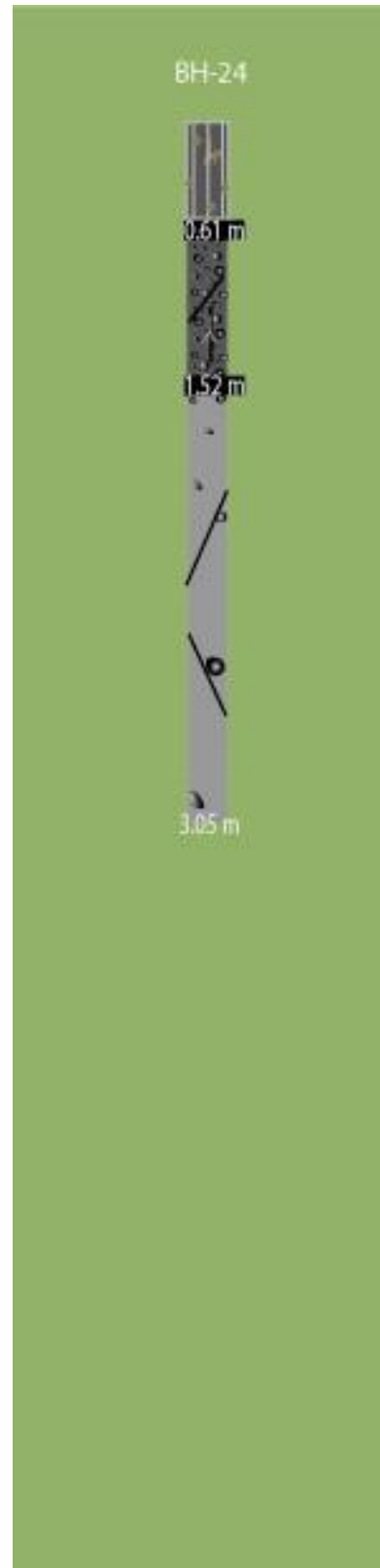
With a surface elevation of 1780.95 meters, core 23 was drilled to a total depth of 3.20 meters. Highly vesicular basalt is found in the first 1.68 meters.

Ropey texture was present in two places one at 0.46 meters and the other at 1.07 meters. Sample P908 was taken from this first section. At 1.6 meters the core becomes massive with few vesicles and remains this way to the bottom of the hole.



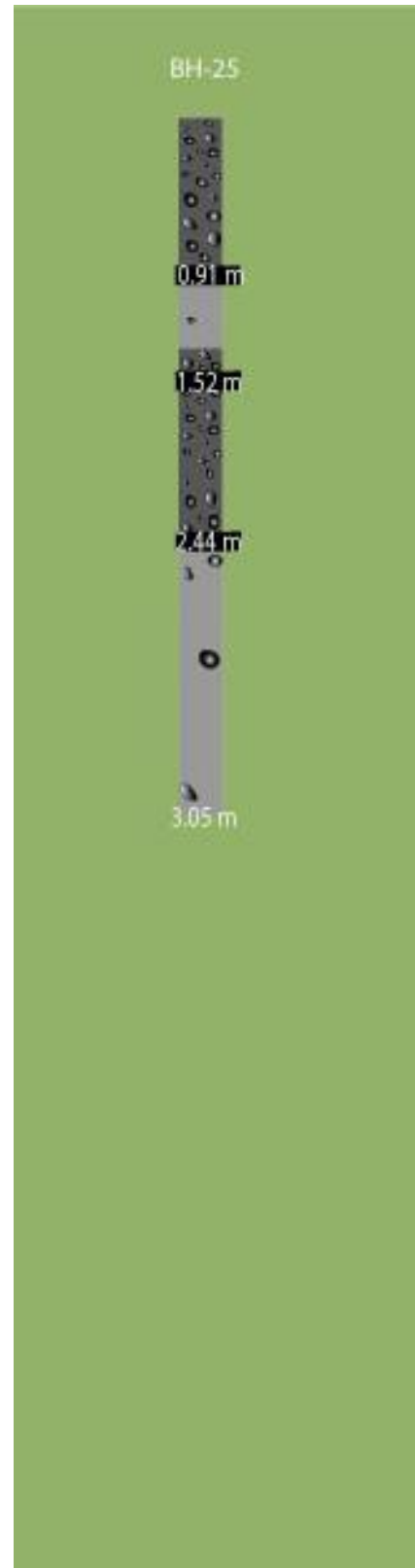
BH-24

With a surface elevation of 1780.95 meters, core 24 was drilled to a total depth of 3.05 meters. From the surface to 0.61 meters, loose rock and soil is present. Below 0.61 meters the basalt is highly vesiculated and contains joints at angles of 90 and 45 degrees between 1.22 and 1.52 meters. Below 1.52 meters the core transitions to a massive basalt and has some 70 degree joints between 1.52 and 1.67 meters.



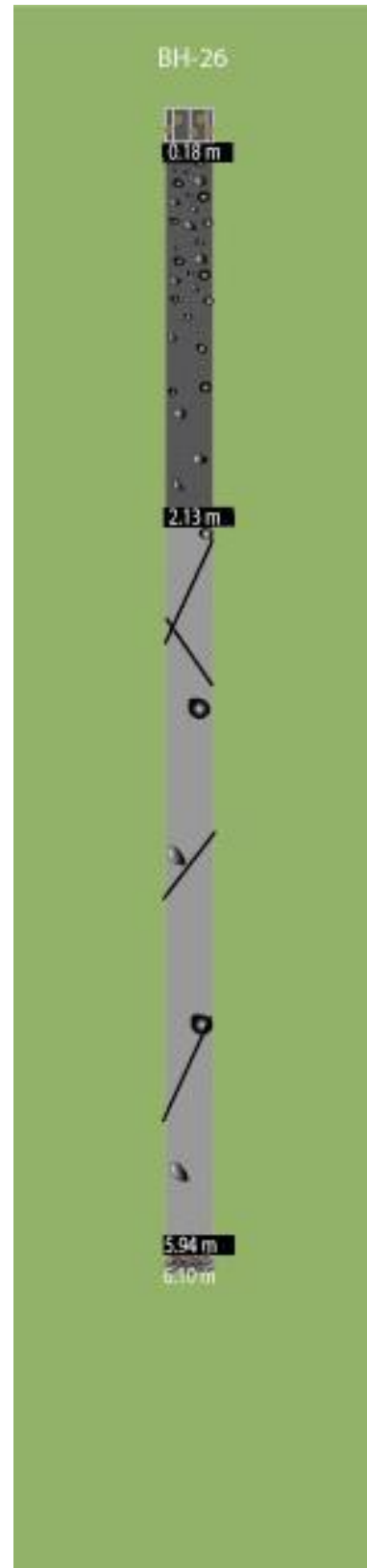
BH-25

With a surface elevation of 1780.79 meters, core 25 was drilled to a total depth of 3.05 meters. Core is highly vesiculated with vesicle size increasing with depth down to 0.9 meters. At 0.9 meters the basalt becomes more massive with a slightly vesicular section between 1.37 to 1.52 meters. Below 1.52 meters the core becomes highly vesicular down to 2.44 meters. At this depth the core transitions back to massive basalt and stays this way to the base of the hole. Within the deepest section of massive basalt there is a void between 2.74 and 2.89 meters.



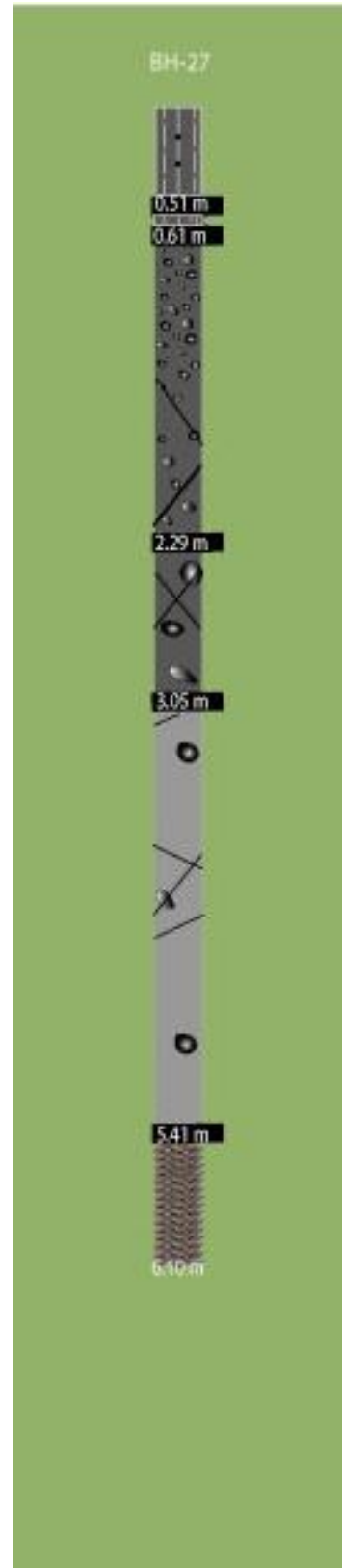
BH-26

With a surface elevation of 1784.00 meters, core 26 was drilled to a total depth of 6.10 meters. The top 0.18 meters of the core is loose rock and soil. Below 0.2 meters the core transitions to highly vesiculated basalt and then again to massive basalt at about 2 meters and remains massive until the bottom of borehole. Jointing at 45 and 70 degree angles is found between 3.51 and 5.64 meters. Sample P909 was removed from 4.42 to 4.57 meters.



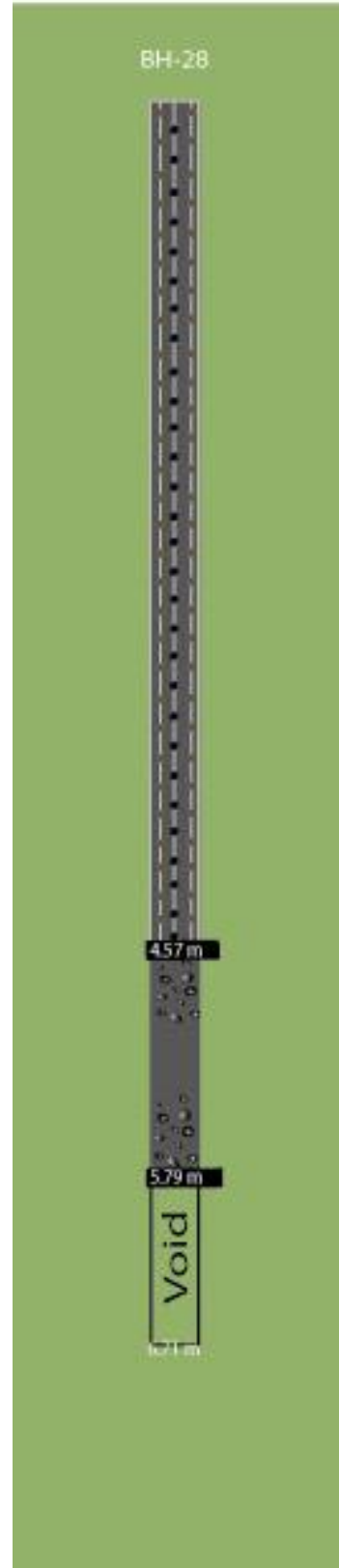
BH-27

With a surface elevation of 1784.28 meters, core 27 was drilled to a total depth of 6.10 meters. From the surface to 0.51 meters roadway embankment was found. A thin layer (100 millimeters) of highly weathered clay and rock follows. Highly vesiculated basalt lies beneath the clay and rock, continuing down to 2.29 meters. There are three joints, one at 1.83, 2.13, and 2.74 meters. At 3.05 meters the core changes from vesicular to massive and contains joints at 20 degree angles at 3.20, 3.89, and 4.27 meters. There is also a 45 degree joint at 4.04 meters. At 5.41 meters there is a clear contact from massive basalt to basalt with a ropey/pahoehoe texture.



BH-28

With an elevation of 1783.93 meters, core 28 was drilled to a total depth of 6.71 meters. Roadway embankment makes up the majority of this core. From 4.6 to 5.8 meters the core contains highly vesiculated basalt. The bottom of the core, from 5.79 to 6.71 meters is a void. This void could be the result of either a lava tube or a section of non-recovery during the drilling process. The field log boring report does not explain the significance of this void.



Discussion

Creating a fence diagram from the borehole data allowed us to achieve a better understanding of the lava flows (Diagram 1). The Tom Cat Hill, East cores, display many lava features that would not have been otherwise observed. We know from previous geologic mapping in the area (Kuntz et al, 1986) that the surface flow the boreholes sampled is the Grassy Cone flow. With the third dimension available from the cores we can see how the thickness of the flow varies from location to location.

‘Idealistically, thicker lava flows can be separated into four sections: vesicular flow top, upper colonnade, entablature, and the lower colonnade. The vesicular flow top is the surface layer of the lava flow that has an abundance of vesicles. Sections with reasonably straight columns of rock are called colonnades. When the columns go in every which way the section is considered to be entablature. In a single lava flow these sections can repeat and/or be missing, pending on the properties as the lava and the surface it is flowing over’ (Winter, 2001). Lava flows similar to water; due to the affects of gravity. However, viscosity (resistance to flow) has major influence on lava. With a low viscosity basalt is much more fluid than most lava types thus basaltic lava features can differ significantly.

The predominate feature seen is the texture of the rock which indicates the nature of the flow. The ropey texture is commonly seen in low viscosity basaltic flows, also known as pahoehoe flows (Winter, 2001). As lava cools the viscosity increases thereby evolving into the opposite end-member type a ‘a. Ropey textures are usually observed on the surface, but it is possible to see this texture within a flow (e.g. BH-23). The pahoehoe flow at the bottom of BH-26 and BH-27 may actually be indicative of a new flow. This flow may be the Sunset Cone pahoehoe flow, the evidence supporting this is the ages of the surrounding lava flows were younger than the Grassy Cone flow except for the Sunset Cone Pahoehoe Flow and the Carey A ‘A flow. And since the location of the ropey texture was at greater depth within the core after a significant amount of massive basalt highly suggests a separate flow.

The vesicular texture is usually observed in the upper sections of lava flows due to escaping gasses. When the surface of the vesicles are oxidized, the holes turn from black to a red from the high content of iron within the rock composition (BH-10) The density and size of vesicles are dependent the amount of gas realized while the rock was cooling.. Generally, vesicles decrease in density and size as depth increases transitioning into a massive texture (e.g. BH-7). However, often larger gas bubbles are trapped at greater depths creating larger size vesicles within the transition and/or massive zones (e.g. BH-20). As the lava flow abuts into the Pioneer Mountains it must abruptly change flow direction where inflation can occur. Repeating sections of vesicular to massive textures happen frequently since the cores were taken at the edge of the lava flow. The toes of the lava flow are also where the lava tubes channel hot lava over the cooled rock (BH-25).

Another cooling feature of the rock and seen abundantly is joints. Cooling joints occur when the rock loses cohesion while solidifying. These joints create the column pattern within the colonnade and entablature divisions. Most of the jointing seems to occur within the massive

sections of the core samples; nevertheless the joints are also present within the vesicular zones as well (BH-12). In a few of the upper vesicular zone joints were filled with soil and roots which quite possibly have percolated and grown down through the vesicles (BH-13). But it is a bit mysterious to find soil and roots within the massive zone at greater depths (BH-22).

Regularly, soil and roots are present at the surface due to weathering, erosion, and deposition of the local bedrock. Rightly so, many of the cores contain a thin layer of soil, and sometimes with roots (BH-8), while other cores contain road embankment (BH-28). At times the bedrock lava is uncovered and directly at the surface (BH-3), but by drilling cores, observations below the soil and weathered bedrock can be made.

Cataloged cores are available for donation to schools or education institutes. If interested please contact Doug Owen via email: Doug_Owen@nps.gov or phone: (208) 527-1331.

Work Cited

Shawn Enright, Idaho Department of Transportation, District 6

Glen Carpenter, Sage Earth Science

Bates, R.L., and Jackson, J.A., 1984, *Dictionary of Geological Terms*: ed. 3, New York, Anchor Books, 571 pages.

Kuntz, M.A., Champion D.E., Spiker, E.C., and Lefebvre, R.H., 1986, *Contrasting magma types and steady-state, volume-predicable, basaltic volcanism along the Great Rift, Idaho*: Geological Society of America Bulletin, v. 97, p. 579-594.

Kuntz, M.A., Skipp, Betty, Champion, D.E., Gans, P.B., Van Sistine, D.P., and Snyders, S.R., 2007, Geologic map of the Craters of the Moon 30' x 60' quadrangle, Idaho: U.S. Geological Survey Scientific Investigations Map 2969, 64-p. pamphlet, 1 plate, scale 1:100,000.

Winter, J.D., 2001, *An Introduction to Igneous and Metamorphic Petrology*: New Jersey, Prentice-Hall Inc., 695 pages.

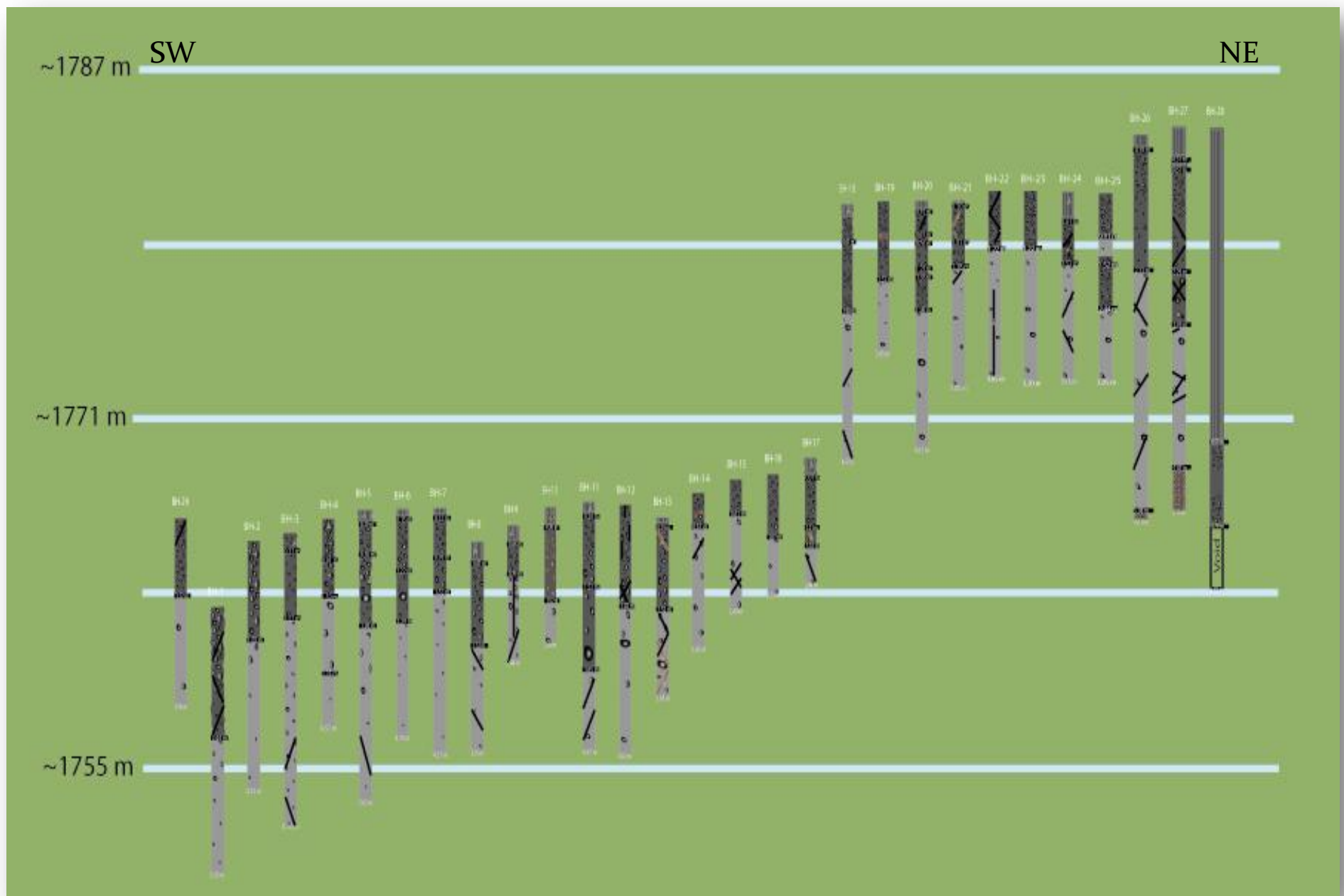


Diagram 1: Displaying all 29 cores from the Tom Cat Hill, East project. Diagram shows relationship between boreholes based on their elevation and location along Highway 20/26/93. Depth from surface is a relative scale. Legend is located in Table 2.